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Constraints on the pMSSM from searches for squarks and gluinos by ATLAS

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Abstract: We study the impact of the jets and missing transverse momentum SUSY analyses of the ATLAS experiment on the phenomenological MSSM (pMSSM). We investigate sets of SUSY models with a flat and logarithmic prior in the SUSY mass scale and a mass range up to 1 and 3 TeV, respectively. These models were found previously in the study 'Supersymmetry without Prejudice'. Removing models with long-lived SUSY particles, we show that 99% of 20000 randomly generated pMSSM model points with a flat prior and 87% for a logarithmic prior are excluded by the ATLAS results. For models with squarks and gluinos below 600 GeV all models of the pMSSM grid are excluded. We identify SUSY spectra where the current ATLAS search strategy is less sensitive and propose extensions to the inclusive jets search channel.

Keywords: Supersymmetry, MSSM, ATLAS, LHC

Contents

1 Introduction

Supersymmetry[1] is one of the conceivable extensions of the Standard Model (SM). It could provide a natural candidate for cold dark matter and stabilise the electroweak scale by reducing the fine tuning of higher order corrections to the Higgs mass. Supersymmetry (SUSY) proposes superpartners for the existing particles. Squarks and gluinos, superpartners of the quarks and the gluon are heavy coloured particles, which can decay to jets and the Lightest Supersymmetric Particle (LSP), i.e. the neutralino. The neutralino is only weakly interacting and stable since we assume the conservation of R-parity. The LSP escapes detection which results in missing transverse momentum in the detector. Channels with jets and missing transverse momentum have a large discovery potential at the LHC [2], since the coupling strength of the strong force would cause an abundance of squarks and gluinos if these particles are not too heavy. The ATLAS collaboration has analysed their data to search for squarks and gluinos in events with 2-4 jets and missing transverse momentum corresponding to an integrated luminosity $L_{\rm int}$ of 35 pb^{-1} in Ref. [3] and 1.04 fb^{-1}in Ref. [4]. No excess above the SM background expectation was observed in the analysed data. Although these searches are designed to be quite independent of SUSY model assumptions, mass limits are presented only for a constrained Minimal Supersymmetry Standard Model (cMSSM) model and for simplified models with only squarks, gluinos and the lightest neutralino.

We will study the exclusion range of the ATLAS search for phenomenological MSSM (pMSSM)[5] scenarios, which have a more diverse spectrum of characteristics than the cMSSM. We identify some of the regions in the pMSSM parameter space where the current search strategy is insensitive.

In the pMSSM the more than 120 free parameters of the MSSM are reduced to 19 by demanding CP-conservation, minimal flavor violation and degenerate mass spectra for the 1st and 2nd generations of sfermions. In addition it is required that the LSP is the neutralino $\tilde{\chi}_1^0$. The 19 remaining parameters are 10 sfermion masses[1], 3 gaugino masses $M_{1,2,3}$, the ratio of the Higgs vacuum expectation values tan β, the Higgsino mixing parameter μ, the pseudoscalar Higgs boson mass m_A and 3 A-terms $A_{b,t,\tau}$. This work is based on "Supersymmetry Without Prejudice"[6]. The model points presented in [6] are used for our purpose. Each model point was constructed by a quasi-random sampling of the pMSSM parameters space. The points were required to be consistent with the experimental constraints prior to the LHC [6].

2 Event generation, Fast Simulation and Analysis

We study the reach of the ATLAS search by emulating the ATLAS analysis chain. First we generate events from LHC collisions for each pMSSM SUSY model with a Monte Carlo generator for SUSY processes. These events are then simulated by a fast detector simulation and the acceptance and efficiency is determined by applying the most important ATLAS analysis cuts on the simulated events. Finally these numbers are used to calculate the expected number of signal events for each signal region and analysis. These numbers are compared to the model-independent 95% C.L. limits provided by ATLAS.
PYTHIA 6.4[7] is used for the event simulation of proton-proton collisions at a 7 TeV centre-of-mass energy. All squark and gluino production processes are enabled as they are of most importance for the inclusive jets search channel. For every model point 10000 events are generated which we found to be enough even for the models with the largest cross sections. To get as close as possible to the ATLAS analysis we use DELPHES 1.9[8] as a fast detector simulation with the default ATLAS detector card, modified by setting the jet cone radius to 0.4. The PYTHIA output is read in by DELPHES in HepMC format, which is produced by HepMC 2.04.02[9]. The object reconstruction is done by DELPHES, which uses the same anti-k_T jet algorithm[10] as ATLAS. Also included in the reconstruction are isolation criteria for electrons and muons. We do not emulate pile-up events.
Reconstructed events are analysed with the same event selections as used by the ATLAS analysis with 35 pb^{-1} (shown in Table 1) and also with the event selections used in the 1.04 fb^{-1} analysis (see Table 2). In these Tables $\Delta\phi(\mathrm{jet}_i, \mathrm{E}_\mathrm{T}^\mathrm{miss})_{min}$ is the minimum of the azimuthal angles between the jets and the 2-vector of the missing transverse momentum $\vec{E}_T^\mathrm{miss}$. The invariant mass m_eff is calculated as the scalar sum of $\mathrm{E}_\mathrm{T}^\mathrm{miss}$ and the magnitudes of the p_T of the leading jets required in the selection (i.e. 2 jets for the 2-jet selection in region A), except for signal region E, where m_eff is the sum of $\mathrm{E}_\mathrm{T}^\mathrm{miss}$ and all reconstructed jets with p_T > 40 GeV. In addition to these cuts a veto on electrons and muons with p_T> 20 GeV was required.

After this selection the event counts are scaled to the luminosities considered in the analyses, i.e. 35 pb^{-1} and 1.04 fb^{-1}, respectively. The NLO cross section used for this is

[1]The sfermion parameters are $\tilde{Q}_\mathrm{L}$, $\tilde{Q}_3$, $\tilde{L}_1$, $\tilde{L}_3$, $\tilde{u}_1$, $\tilde{d}_1$, $\tilde{u}_3$, $\tilde{d}_3$, $\tilde{e}_1$ and $\tilde{e}_3$.

calculated by LHC-Faser light[11, 12] from PROSPINO2.1 [13, 14] cross section grids. The limits on the effective cross sections given by the ATLAS analyses are used to calculate a limit on the number of signal events passing the cuts, also given in Table 1 and 2. No attempt was made to include theoretical uncertainties. In the studied SUSY mass range these uncertainties are small compared to the differences of the ATLAS and DELPHES setups and would not change drastically any conclusion of this work.

Signal region:	A	C	D
E_T^{miss} [GeV]		for all regions >100	
leading jet p_T [GeV]		for all regions >120	
2nd jet p_T [GeV]	>40	>40	>40
3rd jet p_T [GeV]	-	>40	>40
$\Delta\phi(\text{jet}_i, E_T^{miss})_{min}$		for all regions >0.4	
m_{eff} [GeV]	>500	>500	>1000
$f{=}E_T^{miss}/m_{eff}$	>0.3	>0.25	>0.25
95% C.L. limit on σ [pb]	1.3	1.1	0.11

Table 1. Requirements for the signal regions A,C and D for the ATLAS analysis with an integrated luminosity of 35 pb^{-1}. In addition the number of reconstructed leptons has to be zero; also shown are the 95% C.L. upper limits on the cross section for new physics processes σ.

Signal region:	A	B	C	D	E
E_T^{miss} [GeV]			for all regions >130		
leading jet p_T GeV			for all regions >130		
2nd jet p_T [GeV]	>40	>40	>40	>40	>80
3rd jet p_T [GeV]	-	>40	>40	>40	>80
4th jet p_T [GeV]	-	-	>40	>40	>80
$\Delta\phi(\text{jet}_i, E_T^{miss})_{min}$			for all regions >0.4		
m_{eff} GeV	>1000	>1000	>500	>1000	>1100
$f{=}E_T^{miss}/m_{eff}$	>0.3	>0.25	>0.25	>0.25	>0.3
95% C.L. limit on σ [fb]	22	25	429	27	17

Table 2. Requirements for the signal regions A - E for the ATLAS analysis with an integrated luminosity of 1.04 pb^{-1}. In addition the number of reconstructed leptons has to be zero; also shown are the 95% C.L. upper limits on the cross section for new physics processes σ.

In order to compare our setup to ATLAS we determined the relative efficiency difference

$$\frac{\Delta C}{C} = \frac{(A*E)_{\text{ATLAS}} - (A*E)_{\text{DELPHES}}}{(A*E)_{\text{ATLAS}}}$$

for each SUSY point studied by ATLAS in the m_0-$m_{1/2}$ plane for the cMSSM grid with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$. Here $A * E$ is the acceptance times efficiency of the ATLAS and DELPHES analysis setups.

m_0	$m_{1/2}$		Accepted fraction of signal events per signal region A	B	C	D	E
340	120	ATLAS	0.001	0.002	0.08	0.002	0.003
		DELPHES	0.002±0.0004	0.003±0.0005	0.06±0.003	0.003±0.0005	0.004±0.0006
	300	ATLAS	0.1	0.13	0.19	0.11	0.09
		DELPHES	0.15±0.004	0.14±0.004	0.16±0.004	0.1±0.003	0.06±0.003
	450	ATLAS	0.27	0.26	0.23	0.2	0.15
		DELPHES	0.33±0.006	0.27±0.005	0.18±0.004	0.17±0.004	0.11±0.003
1140	120	ATLAS	0.002	0.003	0.08	0.004	0.004
		DELPHES	0.003±0.0006	0.004±0.0006	0.06±0.002	0.004±0.0006	0.003±0.0005
	300	ATLAS	0.05	0.07	0.13	0.08	0.14
		DELPHES	0.05±0.002	0.07±0.003	0.1±0.003	0.07±0.003	0.09±0.003
	450	ATLAS	0.12	0.16	0.18	0.16	0.2
		DELPHES	0.09±0.003	0.09±0.003	0.08±0.003	0.08±0.003	0.1±0.003
2500	120	ATLAS	0.0001	0.002	0.07	0.002	0.003
		DELPHES	0.001±0.0003	0.002±0.0004	0.07±0.003	0.002 ±0.0004	0.003±0.0005
	300	ATLAS	0.02	0.05	0.12	0.07	0.11
		DELPHES	0.02±0.001	0.04±0.002	0.08±0.003	0.04±0.002	0.07±0.003
	360	ATLAS	0.03	0.07	0.13	0.08	0.15
		DELPHES	0.03±0.002	0.04±0.002	0.07±0.003	0.05±0.002	0.08±0.003

Table 3. Accepted signal fraction ($E * A$) for the ATLAS and DELPHES setup and shown for the analysis with $L_{\text{int}} = 1.04$ fb^{-1}.

Figure 1 shows $\frac{\Delta C}{C}$ for the cMSSM. Numerical examples for the ATLAS and DELPHES efficiencies are shown in Table 3. The efficiency of our setup is found to be in agreement with the ATLAS efficiency[15] on the level of $10 - 30\%$ for the 2- and 3-jet signal regions $A - B$ and SUSY masses around the present ATLAS limits. These limits are ranging for $m_{1/2}$ from $200 - 500$ GeV and go up to intermediate m_0 of 1000 GeV.
At $m_{1/2} < 200$ GeV larger deviations occur. Here both the statistical uncertainty of the ATLAS and DELPHES efficiencies are larger and the selection efficiencies are tiny. The largest deviations occur if in addition m_0 is large. The signal regions are not intended for SUSY signals at $m_{1/2} < 200$ GeV and large m_0 and do therefore not contribute to the search for such SUSY signals. Note that the ATLAS analysis selects always the signal region with the largest exclusion potential for each SUSY model.
For signal region $C - E$ and for the 4 and more jet channels we observe better agreement at low $m_{1/2}$ and slightly worse agreement at $m_0 > 1000$ GeV and $m_{1/2} > 400$ GeV. Here our DELPHES setup underestimates the efficiency by up to $50 - 70\%$. The increased differences at larger jet multiplicities might be caused by the cummulative effects of the the ATLAS and DELPHES jet response.
In view of the mostly smaller efficiencies of DELPHES compared to ATLAS, our study can

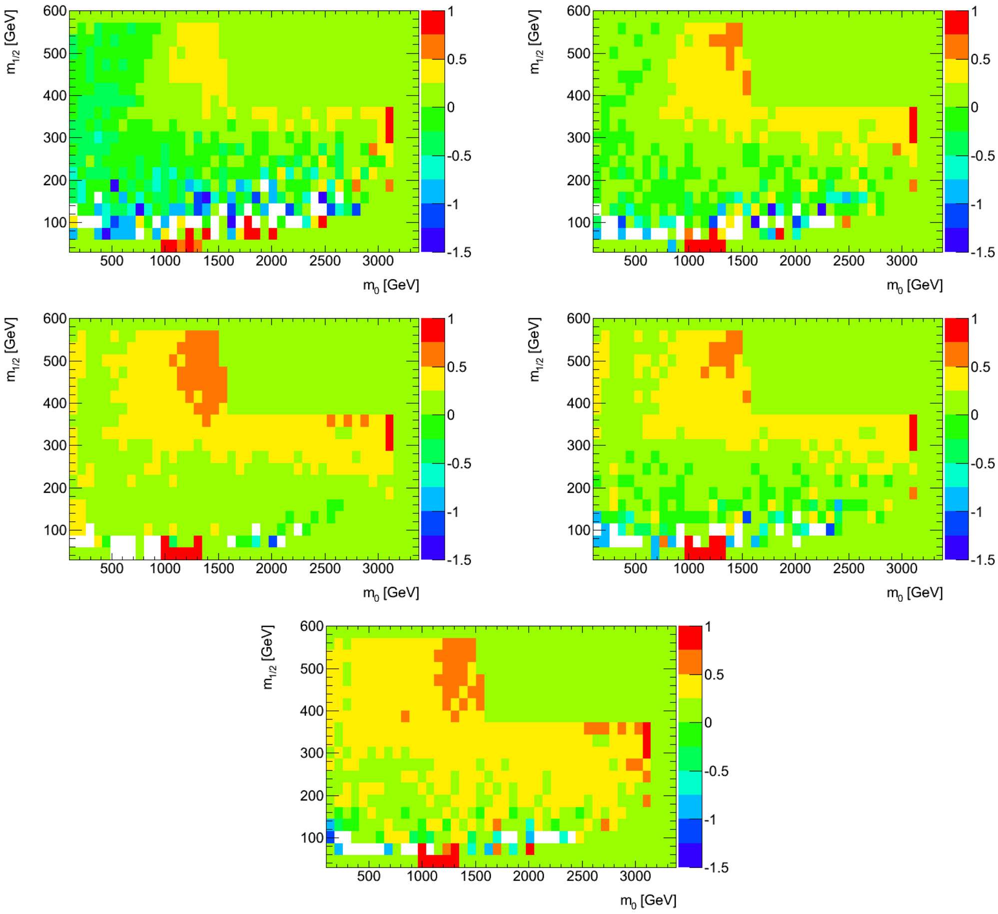

Figure 1. Relative efficiency times acceptance difference $\frac{\Delta C}{C}$ of the ATLAS and DELPHES analysis setups for signal region $A-E$ (top left to bottom right) in the m_0-$\mathrm{m}_{1/2}$ plane of the cMSSM model studied by ATLAS. The difference exceeds the indicated range in the white areas. ATLAS has not provided numbers for the upper right box, here the differences was set to 0.

be regarded as conservative.

3 pMSSM random points

The pMSSM points are taken from "Supersymmetry Without Prejudice"[6] (related work [16, 17]). All details can be found in these references. 19 free parameters were randomly sampled, one set with a flat prior with masses up to 1 TeV and another one with a logarithmic prior and masses up to 3 TeV, each parameter was varied in the range given in Table 4. The parameters are: 10 sfermion masses $m_{\tilde{f}}$; 3 gaugino masses $M_{1,2,3}$; the ratio of the Higgs vacuum expectation values $\tan\beta$; the Higgsino mixing parameter μ; the pseudoscalar Higgs boson mass m_A and 3 A-terms $A_{b,t,\tau}$, the A-terms for the first and second generations can be neglected due to the small Yukawa couplings.

parameter	flat prior set	log prior set
$m_{\tilde{f}}$	100 GeV - 1 TeV	100 GeV - 3 TeV
$\lvert M_{1,2}, \mu \rvert$	50 GeV - 1 TeV	10 GeV - 3 TeV
M_3	100 GeV - 1 TeV	100 GeV - 3 TeV
$\lvert A_{b,t,\tau} \rvert$	0 - 1 TeV	10 GeV - 3 TeV
tanβ	1 - 50	1 - 60
m_A	43.5 GeV - 1 TeV	43.5 GeV - 3TeV

Table 4. Parameter range for flat and log prior model sets

It was assumed that the neutralino is the LSP and that the first two squark generations are degenerate. Several experimental and theoretical constraints[18] are applied on the generated points, i.e. the current dark matter density and constraints from LEP and Tevatron data.
Additionally we have required that the mass splitting between the chargino and the lightest neutralino is Δm > 0.05 GeV with $\Delta m = m_{Chargino} - m_{\tilde{\chi}0}$, to avoid mishandling by PYTHIA. Small mass splittings make charginos stable and PYTHIA yields error messages in the hadronization routines and drops these events. The problem is avoided by a decay of the chargino before the hadronization routine, i.e. by a sufficiently large mass splitting between the chargino and the neutralino. About 1% of the remaining model points could not be generated with PYTHIA due to other compressed mass spectra, i.e. due to very small mass differences between SUSY particles. Here mostly the mass difference of the sbottom or stop to the neutralino was small. These compressed mass spectra lead to long lived squarks which can not be handled by PYTHIA nor by the detector simulation and causes PYTHIA to stop. These model points are dropped. The following studies are therefore not valid if the SUSY model leads to long-lived particles in the spectrum besides the lightest neutralino.

4 Results and Discussion

4.1 Models from a linear prior in the SUSY mass scale

For each SUSY model signal events were generated. Each event was analysed after a detector simulation with DELPHES and the number of signal events was determined for each SUSY model and each of the 8 studied signal regions. In the following we call “excluded models” SUSY models which produced a larger number of signal events than excluded by the ATLAS model-independent limits in at least one of the signal regions studied. The model-independent limits are listed in Table 1 and Table 2. Only the SUSY models which yield less signal events in all regions are not excluded by these ATLAS searches. These models are called “not excluded models”.
Figure 2 and 4 show the 20000 pMSSM model points from a flat mass prior as a function of the lightest mass of the first and second generation squarks M_{squark} and the mass of the

model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}0}$	σ_{NLO}	E_T^{miss}	m_{eff}	N_{Jets}	1^{st} p_T^{jet}	2^{nd} p_T^{jet}	N_{Lep}	$\Delta\phi$
1956	683.7	820.9	127.4	0.4	261.6	999.4	6.5	379.6	235.9	2.2	1.0
2083	672.8	979.8	504.5	0.2	245.4	740.6	4.8	249.7	155.9	0.4	1.2
3226	826.5	645.7	404.3	0.7	179.8	602.3	6.9	212.4	126.3	0.7	1.0

Table 5. Important properties of some not excluded pMSSM models out of 20000. Shown are the mass of the lightest squark in the 1. and 2. generation $m_{\tilde{q}}$; the gluino mass, $m_{\tilde{g}}$; the mass of the lightest neutralino $m_{\tilde{\chi}0}$; the NLO cross section σ_{NLO}; the average values of E_T^{miss}, m_{eff}, the number of jets N_{Jets} and the number of leptons N_{Lep}; 1^{st} p_T^{jet} and 2^{nd} p_T^{jet} are the average of the leading and second highest jet p_T and $\Delta\phi$ is the average of the $\Delta\phi(\text{jet}_i, E_T^{miss})_{min}$ variable.

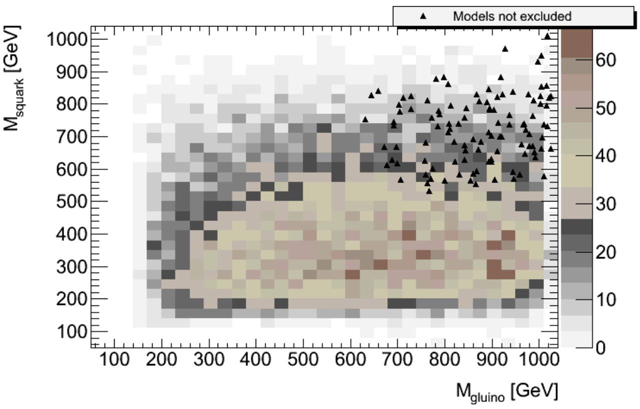

Figure 2. Exclusion range of the ATLAS SUSY analysis for $L_{\text{int}} = 35$ pb^{-1} and $L_{\text{int}} = 1.04$ fb^{-1} for 20000 randomly generated pMSSM points with flat prior as a function of the lightest mass of the first and second generation squarks and the mass of the gluino ; the number of excluded model points for each bin is indicated by the colour scale (bottom figure), not excluded model points are shown in black.

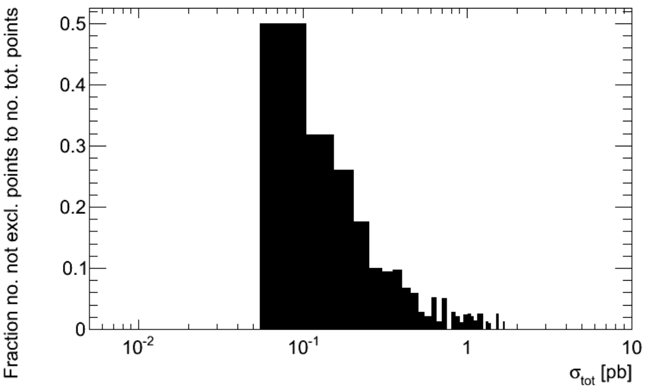

Figure 3. The fraction of the not excluded SUSY models to the total number of studied SUSY models as a function of the NLO cross section for squark and gluino production processes.

gluino M_{gluino}. The SUSY points which are excluded by ATLAS are shown as green points,

models not excluded as black triangles. We show that 99% of the points are excluded with the current ATLAS analyses in the jets and missing transverse momentum channels. All studied points with a mass of the squarks and the mass of the gluino < 600 GeV are excluded. This means that there is not much room anymore in the pMSSM for having both light squarks of the first generations and at the same time a light gluino.

Remarkably, also points with small mass splittings between the squarks or gluino and the neutralino are excluded in this mass range. The reason is quite simple. It is very unlikely that a "random" sampling yields cases where the mass splittings of *all* squarks and the gluino to the neutralino are small. If one of the squarks or only the gluino is a bit heavier than the neutralino such processes yield detectable rates in the ATLAS signal regions. Note that in these models the left and right handed squarks can have quite different masses.

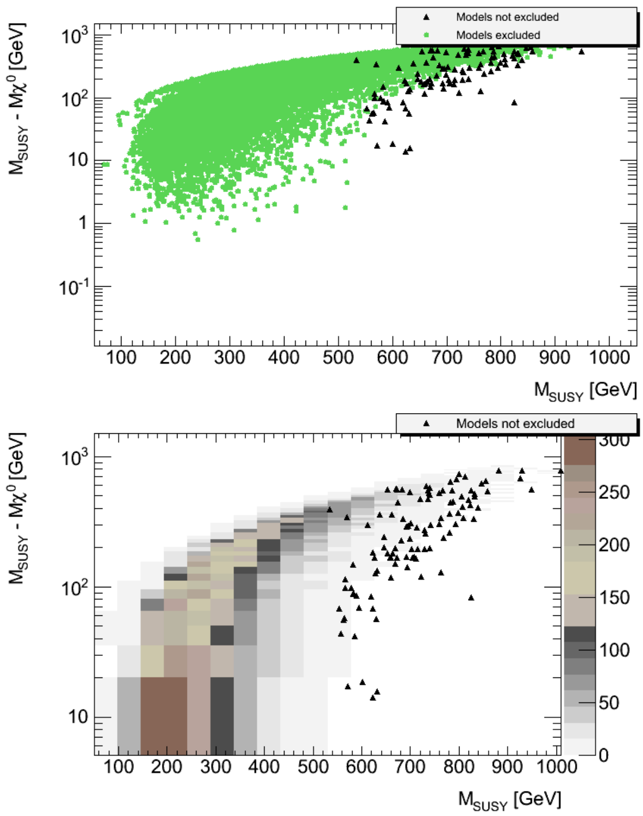

Figure 4. Exclusion range of the ATLAS SUSY analysis for $L_{\rm int} = 35$ pb^{-1} and $L_{\rm int} = 1.04$ fb^{-1} for 20000 randomly generated pMSSM points with flat prior as a function of $M_{\rm SUSY}$ and the mass difference of $M_{\rm SUSY}$ and the mass of the lightest neutralino ; the number of excluded model points for each bin is indicated by the colour scale (bottom figure), not excluded model points are shown in black. The top figure shows the same, but the excluded model points are shown in green.

In Table 5 a subset of the not excluded model points are presented together with some of their properties. A complete list of all not excluded model points can be found in Appendix A.

We found some features why model points are not excluded. We determined average values

for some properties for each SUSY model point, neglecting the fact that these values are coming from different SUSY decay chains. The investigated properties of the non-excluded SUSY models are shown in Table 5. The following features have been found to be significant:

Low cross section A large fraction of model points at high squark and gluino masses cannot be excluded because the cross section is simply too low to be observed for the integrated luminosity . Figure 3 shows the fraction of not-excluded points as a function of the total SUSY squark and gluino cross section. Below 0.1 pb less than 50% of the SUSY models can be excluded with the analysis setup. These are mainly points with a large average effective mass value. At large cross sections of greater 5 pb all studied pMSSM models can be excluded by the ATLAS analyses.

Lepton and multi-jet events (long decay chains) Around 25% of the not excluded model points have a large average number of leptons. In addition we find that these SUSY models do often have a large average number of jets. It is trivial to note that, because of the lepton veto, there is not much sensitivity to these models with the inclusive jets analysis. These points can most likely be excluded with the single or multi-lepton analyses. These searches do have signal regions investigating events with up to 4 jets [19, 20]. Some SUSY models with long decay chains would yield lepton(s) together with multiple jets.

Compressed spectra together with high squark and gluino masses Figure 4 shows the excluded and non-excluded SUSY models from the grid with the flat prior as a function of M_{SUSY} and the mass difference of M_{SUSY} and the mass of the lightest neutralino. In this note, the SUSY mass scale M_{SUSY} is defined as the minimal mass of all first and second generation squarks and the gluino. The figure shows the interesting feature that the non-excluded points are mostly located at small mass differences (relative to M_{SUSY}) and high M_{SUSY}.
Small mass differences between the colored particles and the neutralino yield events with small transverse momentum jets. Figure 5 shows the average effective mass (calculated with the leading 3 jets) as a function of M_{SUSY}. More than half of the not-excluded SUSY models at high M_{SUSY} have an effective mass that is significantly below the value found for the excluded SUSY models. We conclude that the cut on the effective mass is too harsh for these models. For those compressed models the effective mass is differently correlated with the SUSY mass scale.
A lower cut on the effective mass, however, would cause a significant increase in the number of background events. We therefore studied additional features of these non-excluded models. A comprehensive study yields as the most significant feature a large average value of missing transverse momentum. Figure 6 shows the ratio f of the missing transverse momentum over the effective mass as a function of the effective mass. The not-excluded models at $\mathrm{m_{eff}} < 600$ GeV do have average f-values above $0.3 - 0.35$. It is interesting to note that for higher $\mathrm{m_{eff}}$ values smaller cuts on f seem to be appropriate. Increasing the cuts on f for the high $\mathrm{m_{eff}}$ regions seems not to yield to an improved performance.

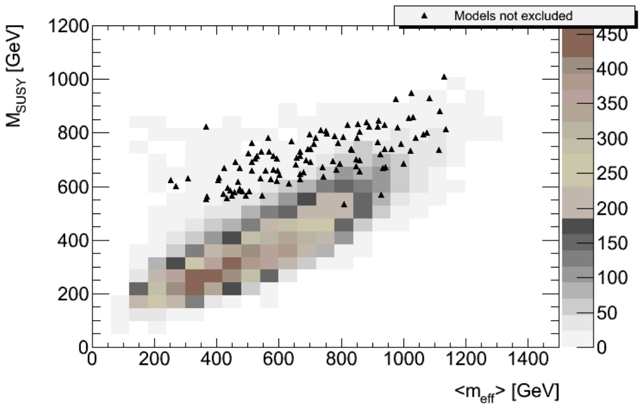

Figure 5. The distribution of m_{SUSY} to the average value of $m_{\rm eff}$ for excluded points (colour scale) and not excluded points (black dots).

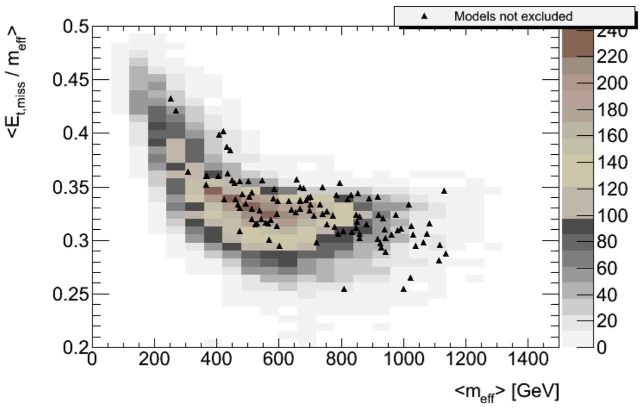

Figure 6. The distribution of the average value $E_T^{miss}/m_{\rm eff}$ to the average value of $m_{\rm eff}$ for excluded points (colour scale) and not excluded points (black dots).

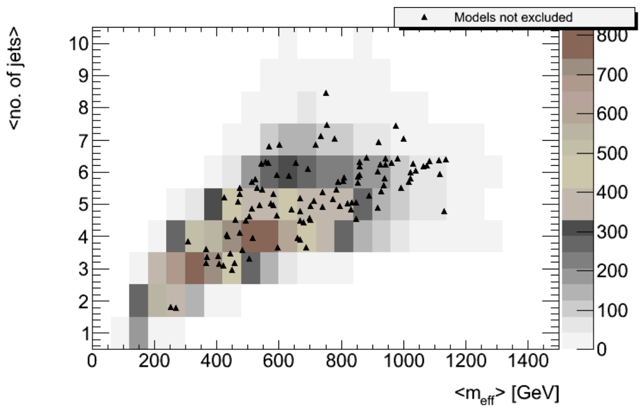

Figure 7. The distribution of the average value of $m_{\rm eff}$ to the average number of jets for excluded points (colour scale) and not excluded points (black dots).

In addition these points do show a typical average jet multiplicity as can be seen in Figure 7, also at $m_{eff} < 600$ GeV. The non-excluded points have jet multiplicities between $2-7$. In conclusion we propose that ATLAS adds to future analyses signal regions with $f > 0.3-0.35$ and a reduced effective mass cut of $m_{eff} > 500$ GeV for high and low jet multiplicities. A similar conclusion has been found for lower jet multiplicities in an independent study dedicated to compressed spectra [21]. Some of the non-excluded points found in our study could be used as benchmark sets to further optimise the cut values with a detailed ATLAS simulation including background events.

4.2 Models from a logarithmic prior in the SUSY mass scale

Figure 8 shows the result of our analysis of 1000 points made with the logarithmic prior up to 3 TeV in the mass scale of SUSY. Excluded points are shown as green points, not excluded ones as black triangles. Due to possible larger masses of the squarks and gluinos more points survive at higher masses. In total we find that 87% of the model points are excluded.

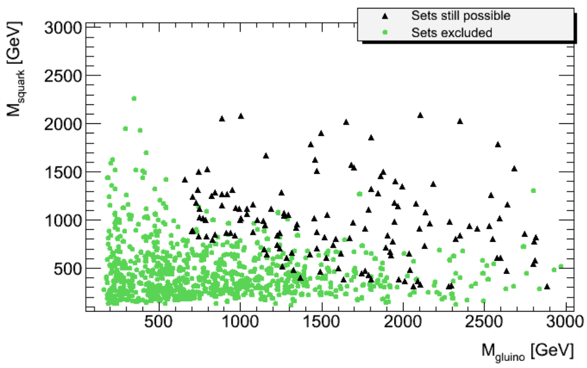

Figure 8. Exclusion range of the ATLAS analyses corresponding to $L_{\rm int} = 35$ pb^{-1} and $L_{\rm int} = 1.04$ fb^{-1} for 1000 randomly generated pMSSM points from a logarithmic prior; excluded model points are shown as green dots, not excluded models as black triangles.

Again around one quarter of the not excluded model points have an average lepton number exceeding one. These points cannot be excluded because of the lepton veto.

A new feature is found in the logarithmic grid. Some SUSY models with gluino masses above 1000 GeV and squark masses between $300-600$ GeV are not excluded. Figure 9 shows the total cross section for squark and gluino production processes as a function of the SUSY mass scale $M_{\rm SUSY}$. All not-excluded SUSY models with $M_{\rm SUSY} < 600$ GeV are close to the *minimal* SUSY cross section at a given value of $M_{\rm SUSY}$. The cross section is minimal since here only the $\tilde{d}_{\rm R}$ and $\tilde{s}_{\rm R}$ or the $\tilde{u}_{\rm R}$ and $\tilde{c}_{\rm R}$ are light. All other squarks and the gluino have much larger mass values.

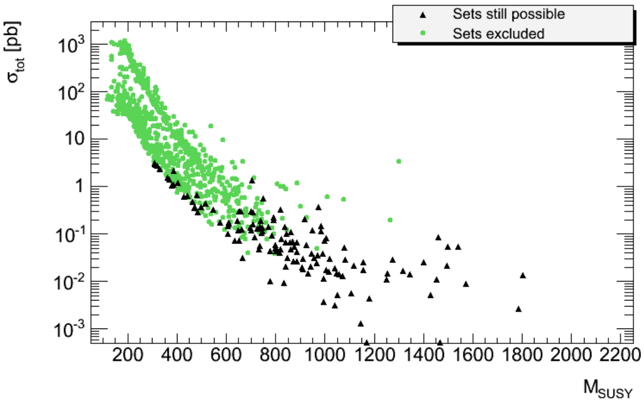

Figure 9. The total NLO squarks and gluino production cross section as a function of the minimal mass of the first and second generation squarks and the gluino m_{SUSY} for excluded model points (green dots) and not excluded models (black triangles). For some high mass model points the cross section is significantly enhanced by sbottom and stop production processes.

These SUSY scenarios might also be missed in future searches, if the cuts on mass scale related variables (as $\mathrm{m_{eff}}$) are raised further. Limits on squark masses derived at a minimum SUSY cross section might be helpful.
In contrast to the flat-prior model points compressed mass spectra do not seem to be an important issue for the log-prior grid as far as we could infer from only 1000 model points.

5 Summary

We show that the "Search for squarks and gluinos using final states with jets and missing transverse momentum" of the ATLAS experiment excludes up to 99% of the model points of the randomly generated pMSSM grid of "Supersymmetry without Prejudice" assuming a flat prior for a SUSY mass scale below 1 TeV. For the model points assuming a logarithmic prior up to 87% are excluded.
Besides the models with a high average number of leptons, the most frequent reasons for the model points not to be excluded are a too low cross section below the discovery potential, a too low mass splitting between the lightest coloured sparticle and the neutralino resulting in a low effective mass $\mathrm{m_{eff}}$. We propose to add selections with an increased missing transverse momentum cut and a decreased $\mathrm{m_{eff}}$ cut, both with low and high jet multiplicities. In addition we find that the search is quite insensitive if only one type right handed squarks is light, i.e. if the SUSY cross section is smaller than usually assumed. These scenarios might also profit from low mass signal regions with minimal statistical and systematic uncertainties.

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A Additional tables

Table 6: Important properties of some not excluded pMSSM models. Masses and energies are given in GeV, the cross section is given in *pb*.

model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}0}$	σ_{NLO}	E_T^{miss}	m_{eff}	N_{Jets}	1^{st} p_T^{jet}	2^{nd} p_T^{jet}	N_{Lep}	$\Delta\phi$
81	741	913	442	0.31	232.7	692.0	5.8	241.2	139.1	0.5	1.2
155	676	963	232	0.39	262.1	847.6	5.1	296.1	187.2	1.0	1.2
175	629	841	502	0.46	230.4	667.8	4.7	239.4	132.4	0.3	1.2
247	805	890	310	0.23	262.4	861.0	6.4	297.8	188.3	1.6	1.1
638	930	999	145	0.1	351.9	1083.1	6.1	377.4	231.5	1.5	1.1
949	652	991	472	0.4	234.6	678.1	4.0	246.5	139.2	0.2	1.3
965	740	829	232	0.3	281.6	941.7	6.4	336.9	210.2	1.6	1.1
1294	880	782	416	0.29	222.0	719.1	7.0	234.6	153.6	1.0	1.1
1446	601	775	583	1.51	112.1	269.9	2.4	102.7	39.2	0.0	1.6
1956	684	821	127	0.44	261.6	999.4	6.5	379.6	235.9	2.2	1.0
2001	824	910	402	0.2	305.5	891.5	5.2	322.1	180.5	1.2	1.2
2041	566	908	469	1.09	159.5	449.5	3.5	164.0	88.5	0.4	1.4
2083	673	980	504	0.2	245.4	740.6	4.8	249.7	155.9	0.4	1.2
2157	809	872	473	0.19	247.3	733.2	6.6	251.1	143.8	1.0	1.1
2324	566	707	452	1.38	165.0	493.6	4.9	165.0	101.4	0.3	1.3
2409	553	866	485	1.51	132.7	366.2	3.3	132.5	68.7	0.2	1.4
2519	655	911	101	0.4	266.6	860.1	5.9	299.1	182.8	2.3	1.0
2577	839	944	434	0.2	283.1	882.4	6.1	312.3	188.4	0.7	1.1
2953	760	772	456	0.39	236.0	711.5	5.4	245.5	145.1	0.7	1.2
3226	827	646	404	0.73	179.8	602.3	6.9	212.4	126.3	0.7	1.0
3469	714	895	429	0.31	232.2	667.4	5.5	228.6	129.1	0.5	1.2
3666	782	787	520	0.38	183.3	565.1	6.4	192.3	114.7	0.7	1.1
3806	692	860	402	0.37	237.1	700.4	5.4	246.0	139.3	0.8	1.2
3809	724	811	604	0.39	173.9	503.3	4.7	171.6	100.8	0.6	1.3
4072	665	1026	483	0.29	206.6	583.6	4.8	209.8	109.0	2.1	1.2
4125	831	923	334	0.15	302.7	854.7	6.4	284.7	165.6	1.2	1.2
4293	741	968	167	0.23	298.9	961.9	5.7	336.2	210.2	2.1	1.1
4383	584	760	497	1.13	158.6	473.4	4.8	163.3	95.2	0.2	1.2
4570	800	703	509	0.61	194.1	593.6	5.6	201.7	120.9	0.3	1.1
5052	759	842	238	0.39	315.6	993.8	5.6	370.9	216.8	2.1	1.2
5312	558	765	514	1.02	163.5	433.5	3.7	156.7	75.1	0.6	1.3
5325	740	809	542	0.3	238.8	702.8	5.0	242.4	145.5	0.3	1.2
5360	737	938	262	0.39	263.5	835.3	5.3	285.5	181.4	1.4	1.2
5497	855	1005	207	0.11	349.6	1016.7	5.6	368.2	210.6	0.8	1.2
5700	623	899	555	0.71	148.0	405.4	3.5	146.9	74.9	0.1	1.4

Table 6: Important properties of some not excluded pMSSM models. Masses and energies are given in GeV, the cross section is given in *pb*.

model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	E_T^{miss}	m_{eff}	N_{Jets}	1^{st} p_T^{jet}	2^{nd} p_T^{jet}	N_{Lep}	$\Delta\phi$
5707	618	698	534	0.91	157.6	468.1	5.1	156.6	92.7	0.0	1.2
5805	699	916	164	0.45	275.5	860.8	5.8	307.1	180.6	1.6	1.1
6232	786	729	536	0.6	178.3	543.6	5.6	180.2	112.3	0.2	1.2
6333	825	730	456	0.49	177.8	568.0	7.3	203.6	112.7	0.9	1.0
6880	638	993	281	0.46	255.9	741.3	4.6	260.7	148.6	0.8	1.2
7105	632	900	616	0.53	160.4	408.0	2.8	150.5	69.0	0.1	1.5
7426	746	692	523	0.75	169.0	512.6	5.6	174.1	103.3	0.2	1.1
7514	661	871	493	0.52	205.0	596.3	4.4	212.0	120.8	0.3	1.3
7727	534	767	139	1.16	210.9	809.2	6.0	293.1	188.7	2.5	1.0
7736	846	895	227	0.19	303.9	921.0	6.5	309.8	190.1	1.4	1.1
7751	782	903	144	0.23	311.2	1041.0	6.0	381.1	231.4	1.7	1.1
7782	586	860	544	0.87	167.8	443.1	3.2	164.6	79.2	0.1	1.4
7888	631	688	574	1.68	114.1	308.4	3.5	106.5	57.7	0.1	1.4
7944	821	1023	356	0.16	308.3	980.4	5.6	357.0	217.7	1.2	1.1
8034	714	808	520	0.61	198.6	582.7	4.6	202.2	120.6	0.2	1.3
8396	831	977	499	0.17	279.5	819.1	5.0	296.3	170.3	0.4	1.2
8589	767	938	218	0.25	288.3	918.2	6.3	327.4	199.8	1.5	1.1
8686	572	770	554	0.87	164.4	421.8	3.1	153.4	71.5	0.1	1.5
8915	686	878	353	0.31	278.0	795.4	5.0	280.7	157.4	1.5	1.2
8916	784	895	343	0.19	270.7	852.8	6.0	280.0	183.8	1.3	1.1
9396	707	978	538	0.24	235.9	658.1	4.1	238.2	128.0	1.0	1.3
9497	583	960	435	1.18	167.2	482.9	3.9	174.6	96.5	0.5	1.3
9759	669	672	472	1.23	151.3	475.2	5.6	169.8	95.6	0.4	1.0
9781	563	856	507	1.3	134.9	368.5	3.4	132.7	67.1	0.4	1.4
10019	735	694	552	0.82	158.6	461.0	5.2	159.6	88.0	0.4	1.2
10149	768	789	530	0.41	216.7	639.1	4.9	221.3	129.9	0.4	1.2
10312	594	867	525	0.85	157.6	435.1	3.7	157.1	81.0	0.2	1.3
10531	624	892	610	1.01	107.9	253.5	2.2	97.4	35.4	0.0	1.6
10698	832	866	318	0.21	299.9	939.5	5.9	332.3	201.9	1.4	1.1
10923	841	659	542	0.74	173.9	512.1	5.3	180.3	98.8	0.3	1.1
11017	673	843	114	0.45	291.4	942.7	5.9	328.9	205.3	2.1	1.1
11050	662	1006	304	0.26	271.7	785.6	4.9	278.8	154.1	1.1	1.2
12020	583	830	495	1.09	180.3	503.7	3.4	182.4	100.5	0.0	1.4
12077	670	987	107	0.3	305.0	935.7	5.6	340.2	195.3	2.0	1.0
12942	763	986	424	0.2	250.5	789.8	6.1	281.0	167.6	0.5	1.1
13170	811	763	634	0.32	180.6	514.9	4.4	177.5	99.8	0.3	1.3
13187	622	822	437	0.68	192.0	593.8	5.5	208.8	122.5	0.4	1.1

Table 6: Important properties of some not excluded pMSSM models. Masses and energies are given in GeV, the cross section is given in *pb*.

model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}0}$	σ_{NLO}	E_T^{miss}	m_{eff}	N_{Jets}	1^{st} p_T^{jet}	2^{nd} p_T^{jet}	N_{Lep}	$\Delta\phi$
13484	626	758	459	0.75	184.1	573.9	5.3	192.8	121.9	0.3	1.2
13616	647	970	445	0.48	229.2	667.4	3.9	236.7	140.7	0.1	1.4
13634	949	1006	395	0.09	336.8	1024.6	5.8	358.3	220.3	0.5	1.2
13698	721	971	246	0.4	276.3	925.8	5.5	326.4	205.7	1.7	1.1
13900	795	814	491	0.37	234.1	699.3	5.2	247.8	144.4	0.6	1.2
13938	566	800	508	0.64	190.5	546.7	4.5	194.1	104.3	0.7	1.2
14537	825	1026	273	0.14	311.8	918.1	5.4	327.5	184.0	1.0	1.2
14962	796	1016	125	0.18	320.8	1063.5	5.5	383.2	240.5	1.3	1.1
15788	786	894	240	0.34	257.1	807.2	6.0	286.5	171.9	1.2	1.1
15922	882	799	432	0.21	242.3	755.4	7.2	247.5	158.2	0.9	1.1
15940	859	1015	319	0.13	326.6	1030.4	5.8	372.8	226.7	0.7	1.1
15963	739	967	211	0.28	284.8	832.0	5.3	289.1	163.9	1.0	1.2
16092	682	760	454	0.59	212.8	654.0	5.7	224.3	136.0	0.5	1.2
16179	702	899	393	0.29	280.8	848.2	5.2	303.4	177.4	1.7	1.2
16379	812	988	109	0.14	333.3	1137.5	5.7	412.5	263.7	1.9	1.0
16411	754	632	498	0.97	182.7	539.7	5.2	190.6	103.8	0.4	1.1
16467	699	922	466	0.47	235.3	686.3	4.4	243.7	142.3	0.3	1.3
16539	733	1017	138	0.33	281.6	1022.6	5.8	382.3	241.5	2.0	1.0
16699	670	699	520	1.24	145.6	424.0	5.0	147.1	83.7	0.1	1.2
16722	590	945	505	0.59	172.2	474.5	3.9	174.2	86.9	0.2	1.3
17158	825	1003	741	0.19	131.5	365.5	3.6	126.6	72.0	0.2	1.4
17174	882	919	98	0.17	331.6	1117.8	6.4	410.0	253.1	1.1	1.1
17262	863	807	397	0.23	246.0	752.8	7.6	239.3	156.2	1.0	1.1
17559	820	712	548	0.53	173.7	531.0	5.7	178.3	107.6	0.4	1.1
17632	971	927	249	0.14	328.7	975.1	6.6	344.3	204.3	0.8	1.2
17767	659	844	492	0.4	182.6	556.8	6.1	197.5	108.9	0.5	1.1
18551	737	1010	190	0.19	316.5	1113.0	6.2	417.2	260.9	1.4	1.0
18564	1009	1018	234	0.07	413.2	1130.7	5.4	412.4	229.6	1.0	1.2
18884	802	1003	70	0.13	350.4	1076.5	6.1	400.0	233.0	1.0	1.1
18895	569	947	225	0.4	282.4	929.8	5.4	347.8	203.9	2.7	1.1
19016	776	706	538	0.61	171.4	523.7	5.8	174.9	106.4	0.3	1.1
19229	613	679	316	0.84	212.9	631.6	6.1	221.2	122.1	2.0	1.0
19367	696	1006	403	0.33	251.2	772.1	5.1	278.8	162.1	0.4	1.2
19707	789	845	340	0.26	251.8	779.2	6.6	264.2	160.6	0.8	1.1
19740	578	1011	480	0.96	163.1	457.4	3.2	169.6	91.3	0.0	1.4
19750	731	785	475	0.5	223.0	669.5	5.0	233.2	139.8	0.4	1.2